Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**		
Title: **Onset and Small Island Physics of the m/n=3/2 NTM**		
OP-XP-834	Revision: **0**	Effective Date: Expiration Date: *(2 yrs. unless otherwise stipulated)*
PROPOSAL APPROVALS		
Responsible Author:		Date
ATI – ET Group Leader:		Date
RLM - Run Coordinator:		Date
Responsible Division: Experimental Research Operations		
Chit Review Board (designated by Run Coordinator)		
MINOR MODIFICATIONS (Approved by Experimental Research Operations)		

NSTX EXPERIMENTAL PROPOSAL

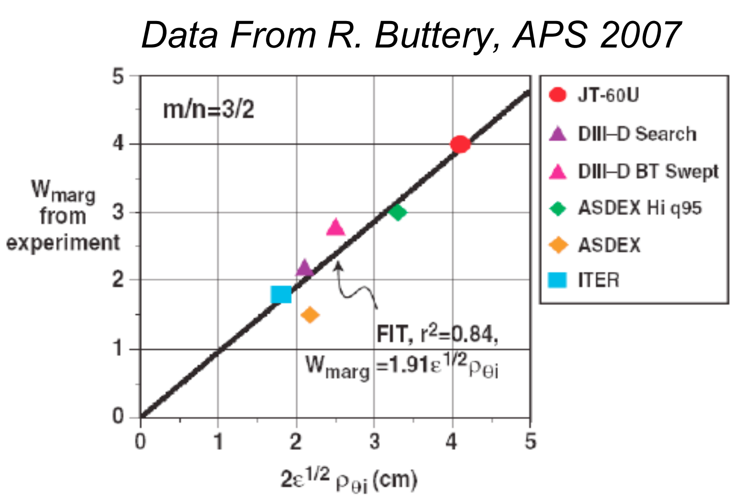
TITLE: **Onset and Small Island Physics of the m/n=3/2 NTM** No. **834**
AUTHORS: **S.P. Gerhardt, D. Gates** DATE: **May 22, 2008**

1. Overview of planned experiment

The purpose of this experiment is to study the 3/2 neoclassical tearing mode (NTM) in NSTX. While this mode is quite common in H-mode tokamaks at conventional aspect ratio, it is not commonly seen in NSTX. Experiments conducted during the present run have demonstrated a scenario where this mode is reliably triggered; the recipe has two ingredients 1) 1 minute of D_2 glow is used, followed by 8 minutes of He glow on a 15 minute shot cycle, and 2) a step in the beam power is used to trigger the mode. The present experiment will use this recipe to study two aspects of the instability. First, an attempt will be made to slowly reduce the plasma β_P, causing the mode to shrink and ultimately disappear all together. The island size where this island quickly disappears is know as the marginal island width (w_{marg}), and is a critical parameter in understanding the small-island physics of the NTM. This ramp-down will be done at three plasma currents (700kA, 900kA, and 1100kA). In the second step, the most successful I_P level will be used to study the restabilization as a function of plasma rotation using n=3 braking. Time permitting, some aspects of the "recipe" will then be studies to determine which elements are most important in allowing access to the mode.

2. Theoretical/ empirical justification

The neoclassical tearing mode is likely to be a beta-limiting instability in any H-mode reactor tokamak plasma. For instance, the 3/2 NTM will result in a ~20% confinement degradation in ITER if allowed to grow to a saturated size. A saturated 2/1 NTM will have even more dramatic consequences, likely locking to the vessel and leading to severe confinement degradation and probable disruption. In NSTX, the m/n =2/1 NTM is commonly observed at the end of any high-performance discharge. This mode has been the focused on, both in terms of devoted XPs, and from large-scale piggyback analysis. The 3/2 mode, however, is typically not present in NSTX; the "discovery" of a recipe to generate this mode this year present an opportunity to study the physics of the 3/2 NTM at low aspect ratio. One particular focus of the experiment will be to study the marginal island width, i.e. the width of the island just before it restabilizes as β is reduced. Many experiments at conventional aspect ratio have found that $w_{m\arg} \approx 2\sqrt{\varepsilon}\rho_{\theta,i}$, where $\rho_{\theta,i}$ is the ion poloidal gyroradius. It is of great interest to confirm this scaling at low aspect ratio, and this is the main focus of the present experiment. An additional important step will study how plasma rotation impacts the saturated island width and small island physics. This is an important step, give that the momentum input to a reactor tokamak is likely to be relatively small compared to typical co-injected tokamaks, from which much (but not all) of the present data is collected.



3. Experimental run plan

Note: The scientific priority of these experiments is as follows:

1. *Restabilization at three values of I_p. (21 shots)*
2. *Dependence of island width and small island physics on rotation. (8 shots)*
3. *Further exploration of the recipe for striking the mode. (4 shots)*

Completion of step 1 only would have great scientific merit, and provide a firm foundation for additional rotation studies next year. It provides the basic level NTM physics needed to move forward in this research area. It is allocated the majority of the shots.

However, if good restabilization is achieved at a single value of I_P and the prospects do not look good at the other currents (due to, for instance, a late start to the run day), the option exists to cut short those attempts and move to step 2.

Step 3 is of the lowest priority.

Step 0: Establish the reference shot with 3/2 mode. (2-5 shots)

3.0.0: If active lithium evaporation was used on the previous day, do a 10 minute D_2 glow, followed by 30 minutes of He glow. This should assist in passivating any lithium and reestablishing conditions that existed during the pre-lithium shots where the 3/2 mode was observed

3.0.1 Reference Shot: 128825 (2 shots)

This is a standard fiducial shot from the standpoint of the plasma shape and fueling.

Use 1 minute D_2 glow, followed by 8 minutes He glow, and a 15 minute shot cycle.

Use the following timing for the three beam sources:

Source A: On at 40

Source B: On at 80msec, off at 390, on at 400

Source C: On at 400, off at 410

The H-mode transition should be delayed until the end of the I_P ramp. The 3/2 mode should strike at ~400 msec and run out until the late 2/1 mode picks up.

3.0.2 Steps to take in case the mode is not present (3 shots)

If H-mode is not delayed to the end of the current ramp and the mode does not strike, keep the D_2 glow while doing the following on sequential shots:

- Increase the D_2 glow from 1 minute to 2 minutes.

- While keeping the D_2 glow the same, add currents in the RWM coils from t=0.0 to t=0.222, with the following magnitudes: [SPA1,SPA2,SPA3]=[2000,2000,-2000] A.[1]

If the H-mode is delayed but the 3/2 mode does NOT strike, try the following steps on sequential shots:

- Swap the times when C and B fire.
- Increase the 10 msec time windows in the beam waveform to 20 msec (i.e. B off at 380 on at 400, C on at 400, off at 420)
- Leave source C on for the entire shot at 400 msec.
- Reduce κ to 2.0
- Reduce κ to 1.8

Step 1: Restabilization of the 3/2 NTM at three different levels of I_P (21 shots)

It is assumed here that Step 0 was successful in generating the mode at a known time during each discharge.

The goal of this section is to reduce β_P by ramping down the NBI power, ultimately leading the restabilization of the mode. The restabilization will need to occur during the ~200-300 msec between the striking of the mode and the start of the typical late 2/1 NTM, which is extremely detrimental to plasma performance.

Using the "standard" n=3 correction ([SPA1,SPA2,SPA3]=[+300,+300,-300]) and n=1 feedback parameters (B_P Gain=1, τ_{BP}=2msec, B_P phase =270, using combined B_P upper and lower sensors) should assist in maintaining good plasma performance through the NBI step-downs.

While it is somewhat difficult to prescribe in advance the exact NBI timing, it is anticipated that the NBI waveforms will follow the following sequence until the restabilization occurs. The modulation should start approximately 30 msec after the mode strikes.

If there are 2 sources (A and B) on after the triggering beam modulation, do the following on successive shots until the mode is either stabilized, or the restabilization is determined to not be possible.

- Leave A on, replace the 2MW source B with a 1MW source C (source C power adjusted through the beam voltage).
- Leave A on, replace the 2MW source B with a 0.6 MW source C (source C power adjusted through the beam voltage).
- Leave A on, turn B off, turn C on at 1MW for a ~20 msec period to smooth the transition to a sigle source.
- Turn B off and modulate A 20 on/20 off. This time can be reduced to 10/10 if the MSE is able to get useful data with shorter on-times.

If there are 3 sources (A, B, and C) on after the triggering beam modulation, do the following on successive shots until the mode is either stabilized, or the restabilization is determined to not be possible.

[1] Note: Data from XP 818 showed the delay of the H-mode transition through the application of large error fields during the I_P ramp.

- Turn off C, Leave A and B on.
- Turn off C, Leave A on and modulate B 10 msec on/10 msec off
- Turn off C, Leave A on and modulate B 10 msec on/20 msec off
- Turn off C, Leave A on and turn B off
- Turn off C, Turn B off and modulate A 20 on/20 off. This time can be reduced to 10/10 if the MSE is able to get useful data with shorter on-times.

If the mode is successfully restabilized, repeat the shot for the sake of improved statistics. Based on the above prescription, it is anticipated that up to 6 good shots will be required in order to restabilize the mode (or determine that restabilization is unlikely to occur).

Additionally, it will be required to take at least 1 reference case with no NBI step-downs for each of the two additional I_P levels (700kA and 1100kA). If the mode doesn't strike at either 700 or 1100 kA using the same prescription as for 900kA, revisit the steps in 3.0.3

The toroidal field, plasma current, and source B voltages are to be selected as in the following table. The source B voltage is adjusted in order to keep constant plasma pressure during the (presumed) change in confinement with increasing I_P and B_T.

B_T	I_P	Voltage on B
3.5	700	90
4.5	900	80
5.5	1100	70

3.1.1: NBI step-down to restabilize the 3/2 NTM at 900 kA: 5 shots

3.1.2: Develop the 3/2 mode target at 1100 kA: 3 shots

3.1.3: NBI step-down to restabilize the 3/2 NTM at 1100 kA: 5 shots

3.1.4: Develop the 3/2 mode target at 700 kA: 3 shots

3.1.5: NBI step-down to restabilize the 3/2 NTM at 700 kA: 5 shots

Step 2: Dependence of Saturated Island Width and Small Island Physcics on Plasma Rotation (8 shots)

The purpose of this section of the experiment is to study how the plasma rotation, or rotation shear, impacts the small island physics and saturated island width. Repeat the most successful case from 3.1.1, 3.1.3, and 3.1.5, with spa currents of 500 and 1000 Amps in the anti-correction phase. SPA currents ramping on from t=0.34 to t=0.37

3.2.1: NBI step-down to restabilize the 3/2 NTM with 400 A anti-correcting n=3 field: 4 shots
RWM coil currents as [SPA1, SPA2, SPA3]=[-400,-400,+400]

3.2.2: NBI step-down to restabilize the 3/2 NTM with 1000 A anti-correcting n=3 field: 4 shots
RWM coil currents as [SPA1, SPA2, SPA3]=[-800,-800,+800]

Step 3: Analysis of the "recipe" (4-5 shots)

The purpose of this step is to determine what the critical elements are for triggering the mode with the NBI modulation trigger. The steps are designed to determine the importance of the late H-mode compared to the rapid NBI steps.

3.3.1: Attempt to strike the mode without early H-mode:

- Remove NBI step-downs that were used to restabilize the mode.
- Leave the beam modulations at t~400 for mode triggering.
- Add a "blip" of the unused source from 80-120msec.
- Remove the early D_2 glow, so go to a full 9 minutes of He.

This recipe should produce the standard early H-mode, with a transition at about t=115 msec.

If no mode then go to 3.3.2.

3.3.2: Same recipe as 3.3.1, but with triggering modulation moved to 500 msec. This should allow the q profile to evolve longer before the trigger.

If no mode then go to 3.3.3.

3.3.3: Same prescription for the shot as 3.3.3, but with the following SPA currents from t=0 through t=0.22: [SPA1,SPA2, SPA3]=[2000,2000,-2000] A.

3.3.4: Using the standard recipe for delaying the H-mode, modify the beam trigger on subsequent shots so that they:

- Have only a step up and down of C, with A and B constant.
- Have the step down and up of B, but no step-up in C.

4. Required machine, NBI, RF, CHI and diagnostic capabilities

RWM/EFC coils in the odd-parity configuration

Ability to do both He and D_2 glows.

Source Voltages [A,B,C]=[90,80,90] kV to start with.

Permission to run the TF at 0.55 Tesla.

This experiment CANNOT productively run without ALL of the following diagnostics:

- High-n and Poloidal array Mirnov Sensors: *Mode Identification & Amplitude*
- USXR arrays, starting with 10μm and 100μm filters and then adjusted based on emission characteristics of the plasmas that day: *Island Width and Location*
- CHERS: *Ion temperature magnitude and gradient at q=3/2, critical for determining* $\rho_{\theta,i}$
- MPTS (single laser acceptable, but 2 preferred): *isotherm constraint in equilibrium code, electron pressure gradient at the rational surface as the neoclassical drive*.
- Equilibrium Magnetics: *Equilibrium Constraints*
- MSE: *q-profile*

5. Planned analysis

EFIT 01 and 02 between shots, and MSE constrained equilibria with either LRDFIT or EFIT computed after the day. If the experiment is completed successfully, it is anticipated that some calculation of Δ', likely with the PEST-III code, will be needed. This will likely require TRANSP runs for selected shots.

6. Planned publication of results

If successful, the results will be presented at the typical meetings (APS, ITPA,…). The results from a successful XP would also be suitable for publication in a journal such as Nuclear Fusion. Additionally, the marginal island widths would be added to the database of results from conventional aspect ratio devices.

PHYSICS OPERATIONS REQUEST

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Machine conditions (specify ranges as appropriate)

I_{TF} (kA): 3.5 to 5.5 kA Flattop start/stop (s): standard

I_P (MA): 0.7 to 1.1 Flattop start/stop (s): Longest possible

Configuration: **Standard slightly biased down fiducial shape**

Outer gap (m): **10 cm** Inner gap (m): **6 cm**

Elongation κ: **2.3** Upper/lower triangularity δ: **0.4/0.75**

Z position (m):

Gas Species: **D_2** Injector(s): Standard HFS + LFS

NBI Species: **D** Sources: [A,B,C] Voltage (kV): [90,80,90] Duration (s): Variable

ICRF Power (MW): 0 Phasing: Duration (s):

CHI: **Off** Bank capacitance (mF):

LITER: Off

Either: List previous shot numbers for setup: ***128825***

Or: Sketch the desired time profiles, including inner and outer gaps, κ, δ, heating, fuelling, etc. as appropriate. Accurately label the sketch with times and values.

DIAGNOSTIC CHECKLIST

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Diagnostic	Need	Want
Bolometer – tangential array		
Bolometer – divertor		
CHERS – toroidal	X	
CHERS – poloidal		X
Divertor fast camera		
Dust detector		
EBW radiometers		
Edge deposition monitors		
Edge neutral density diag.		
Edge pressure gauges		
Edge rotation diagnostic		
Fast ion D_alpha - FIDA		
Fast lost ion probes - IFLIP		
Fast lost ion probes - SFLIP		
Filterscopes	X	
FIReTIP		
Gas puff imaging		
Hα camera - 1D		
High-k scattering		
Infrared cameras		
Interferometer - 1 mm		
Langmuir probes - divertor		
Langmuir probes – RF ant.		
Magnetics – Diamagnetism	X	
Magnetics - Flux loops	X	
Magnetics - Locked modes	X	
Magnetics - Pickup coils	X	
Magnetics - Rogowski coils	X	
Magnetics - RWM sensors	X	

Diagnostic	Need	Want
Mirnov coils – high f.	X	
Mirnov coils – poloidal array	X	
Mirnov coils – toroidal array	X	
MSE	X	
NPA – ExB scanning		
NPA – solid state		
Neutron measurements		
Plasma TV		
Reciprocating probe		
Reflectometer – 65GHz		
Reflectometer – correlation		
Reflectometer – FM/CW		
Reflectometer – fixed f		
Reflectometer – SOL		
RF edge probes		
Spectrometer – SPRED		
Spectrometer – VIPS		
SWIFT – 2D flow		
Thomson scattering	X	
Ultrasoft X-ray arrays	X	
Ultrasoft X-rays – bicolor		
Ultrasoft X-rays – TG spectr.		
Visible bremsstrahlung det.		
X-ray crystal spectrom'r - H		
X-ray crystal spectrom'r - V		
X-ray fast pinhole camera	X	
X-ray spectrometer - XEUS		